§3. Tensile Properties of Reduced Activation Ferritic/martensitic Steels after Long Term Aging

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Reduce activation ferritic/martensitic (RAFM) steels, such as F82H, JLF-1 and CLAM, have been developed as the structural materials for fusion blanket. Aging tests for the RAFMs has indicated additional precipitation of MC (M = V, Ta) and Laves phase (Fe_2W). The purpose of the present study is to estimate the effect of the precipitates produced during the long term aging.

Materials used were F82H-IEA heat, JLF-1 JOYO heat and CLAM steels. F82H was aged at 400, 500, 550, 600 and 650 °C for 100 khr. JLF-1 and CLAM were aged at 500, 600 and 650 °C for 2 khr. Vickers hardness test was performed at room temperature with a load of 500 gf and a time for 30 sec. Tensile test was conducted at room temperature. The gauge size of the tensile specimens is 5 x 1.2 x 0.75 mm.

Figure 1 depicts the hardness after the aging. Slight hardening was observed for F81H after aging at 400, 500 and 550 °C. Similar hardening was observed for JLF-1 and CLAM after aging at 550 °C. According to microstructural analysis with X-ray diffraction, transmission electron microscope and extraction residue tests, the hardening is attributed to the additional precipitation of MC. While, softening occurred for all the steels after aging at 600 and 650 °C. X-ray diffraction analysis and extraction residue tests indicated that precipitation of Laves phase was significant at 550 °C and above. Softening was considered to be induced by reduction in tungsten in solution due to the precipitation of the Laves phase. According to the extraction residue tests, W in solution after aging at 550 °C and above could be about 1 wt% which is half the addition amount, 2 wt%. The reason for little softening at 550 °C in spite of W reduction in solution might be comparable hardening by MC precipitation at the temperature.

Figures 2 and 3 plot tensile property data at room temperature for F82H after aging for 100 kh. Behavior of yield stress and ultimate tensile strength was similar to hardness test results, where slight hardening was observed at 400 and 500 °C, whereas softening occurred at 600 and 650 °C. Both uniform elongation and total elongation were increased with decreasing the strength. No degradation of elongation by the slight hardening due to MC precipitation was detected at 400 and 500 °C.

In conclusion, RAFM exhibited negligible change in tensile property at room temperature after the aging for 100 khr at the expected operation temperature for fusion blanket, 550 °C, and below. However, microstructural changes such as MC and Laves phase precipitation were induced during the aging. Since reduction in tungsten in solution by Laves phase precipitation can degrade high temperature strength, high temperature tensile tests and creep tests are planned in near future.

This work was supported by NIFS budget code UFF024, and JAEA-NIFS Joint Work contract No. 25K-296, as a part of Broader Approach activities.

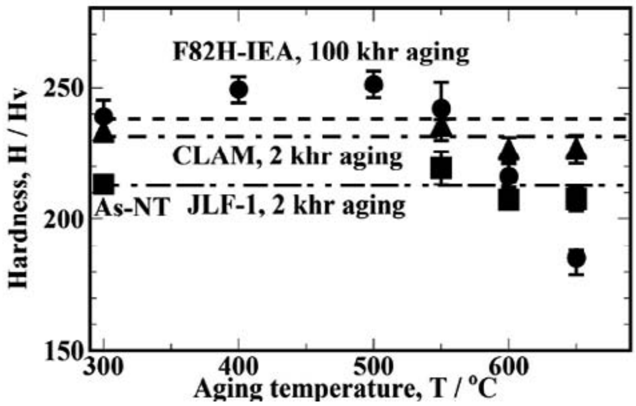

Fig. 1 Vickers hardness after aging for 100 khr for F82H and for 2 khr for JLF-1 and CLAM. The lines indicate the levels for harness at as-normalized and tempered (As-NT) condition before the aging.

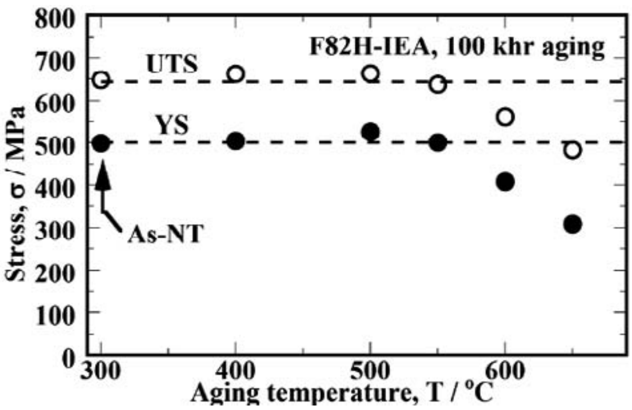

Fig. 2 Yield stress (YS) and ultimate tensile strength (UTS) of F82H at room temperature after aging for 100 khr. The lines indicate the levels for strength at as-NT condition before the aging.

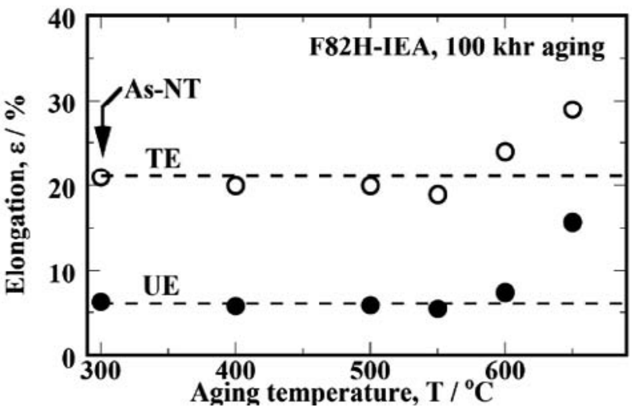

Fig. 3 Uniform elongation (UE) and total elongation (TE) of F82H at room temperature after aging for 100 khr. The lines indicate the levels for elongation at as-NT condition before the aging.